THE NEW STAR IN THE CONSTELLATION OF AURIGA.[1]

THE appearances which the new star has presented were exceedingly remarkable, and observations, both spectroscopic and photometric, were far more numerous than have been obtained during former occurrences of this kind. The latter have been sufficient to establish the unsuitability of several explanations which have been suggested with regard to former new stars, suggestions which at the time appeared more or less plausible. On the other hand, however, it is very difficult to establish, from the publications of observers up to the present time, all details required for a general proof of a definite hypothesis. It appears to me appropriate to suggest a new attempt at explanation, which seems to tally better than others with the principal results of observation, the final tests of which hypothesis must, however, for the present remain a matter for the future. But if this attempt should in the present instance meet with difficulties—a case which I admit to be possible, if not probable—it yet deserves a somewhat more detailed explanation, because it thoroughly takes account of, as I believe, possible conditions, and therefore certainly contains a possible hypothesis with regard to the appearances of certain new stars. In the following remarks I shall strictly adhere to the facts which are to be considered, according to the statements of the observers, as the result of their observations, whereas a proof of the latter is beyond the limit of this article. I may here mention that I have already suggested the most essential of the following remarks in March of the present year.[2]

The chief results of observations, which may be said to contain the characteristics of all the appearances, are:—

1. According to Herrn Lindeman[3] the light-curve of the Nova presented the following appearances:—

"From February 1 to 3 the photometric curve rises quickly to a brightness of 4.7m., then gradually sinks till February 13, and then quicker until February 16 to 5.8m., reaches a second maximum of 5.14m. on February 18, has a second minimum on February 23, likewise of 5.8m., and then a third maximum on March 2 again of 5.4m., upon which it sinks till March 6, slowly at first, and then quicker, in a straight line till March 22 down to 9.3". I may here add that from the photographs taken at Harvard College, it was possible to show that the star became visible from the beginning of December, 1891, that already in the period of time December 20–22 it showed a maximum of brightness which reached almost, but apparently not entirely, a maximum on February 3.

2. The spectrum of the Nova was most remarkable. Prof. Vogel, in summing up the results obtained at Potsdam,[4] writes:—

"The observations have led to the exceedingly interesting result that the spectrum of the Nova consists of two superposed spectra, and that a number of lines, especially those of hydrogen, which appear bright in one spectrum and dark in the other, are closely adjacent to one another. This fact admits of hardly any other explanation than the presence of two bodies, the component motions of which in the line of sight are very considerable; . . . The bodies separate from one another with a relative velocity which during four weeks' observations (in February) suffered no appreciable change, and which amounted to at least 120 miles per second." It may be further added[5] that among the very broadened bright lines there were noted several intensity maxima, two being especially striking.

It has been suggested as an explanation of the facts of observation that two heavenly bodies have passed very close by one another, and that thus changes in their atmospheres have arisen which have caused the sudden brightening up of the bodies. The above hypothesis is, however, in this form too vague to be followed in detail. In reverting to an idea of Klinkerfues, it is true that a more distinct picture of the whole occurrence has been drawn, by assuming tidal effects of the two bodies upon each other: in this manner where the tidal crests of the atmosphere appear, there the darkenings take place by absorption, and where the ebb predominates a brightening is the result, because here the absorbing strata of the atmospheres are less powerful. It must be mentioned, however, that the statical theory of Ebb and Flow that has been applied is altogether inappropriate to give an idea of the deformations which doubtlessly occur at such a near proximity. The effect of the two heavenly bodies on each other in Nova Aurigæ, as is still to be shown, would have to be one that is almost always suddenly appearing and immediately afterwards vanishing. Moreover it must not be overlooked, that with incandescent bodies their atmospheres must be regarded as outward shells which quite gradually emerge into denser strata, while these also are deformed in a lesser degree. In other respects, too, it will be difficult to explain the appearances of a new star as a consequence only of the effects of absorption of atmospheres. It has also been assumed for the most part that besides these (absorptions), eruptions of gas from the centre of the body take place. This assumption, it is true, contains nothing impossible, but without a definite form it hardly admits of discussion. At all events it will be necessary to suggest further hypotheses in order to apply this attempt at explanation to single cases. Moreover, it remains yet unexplained why in Nova Aurigæ the one spectrum is chiefly an absorption spectrum and the other a gas spectrum. By special assumptions this difficulty can be certainly eliminated, but it is not very probable that on this account confidence can be placed in the correctness of the hypothesis.

Other facts appear, however, in the case of Nova Aurigæ which do not speak in favour of this hypothesis, however generally it may be expressed. It is at least very striking that just in this case such enormously great velocities of cosmical bodies appear, such as have hitherto not been found anywhere else. The occurrences of these velocities must therefore be numbered among the facts to be explained. Further on formulæ will be given from which, at least to a certain degree, the mechanical conditions of the close approach of two bodies can be computed. From this it follows that in the case of Nova Aurigæ the two bodies can describe a parabola round each other only if their masses are much larger than 15,000 times the sun's mass. For a hyperbolic movement one can obtain an essentially smaller value of the mass, by assuming that the enormous relative velocity of 120 miles observed has been produced to a small degree by attraction and has existed almost entirely from the beginning. Thus the choice is left between the assumption of extremely large masses or the giving up of an explanation of the great relative velocity. Neither of these two assumptions contain, it is true, an impossibility, but I do not think that doubtful proofs for the correction of the hypothesis can be noticed in either of them. According to my opinion they rather render it (the hypothesis) very little plausible.

The formulæ already mentioned indicate what will be explained further on, namely, that the supposed effect of the two bodies, in the case in hand, must have taken place very quickly indeed, perhaps even in the period of a few hours. This effect must necessarily have occurred upon the first brightening up (beginning of December 1891). Why then the Nova attained several weeks later (beginning of February 1892) a second maximum, and to all appearances a greater maximum, and why the light-curve sank only very little till the beginning of March but afterwards very rapidly, seems to me, on the ground of the hypothesis in question, to be explainable only with great difficulty, if it can be explained at all. At all events, this difficulty will remain unless it be altogether removed in detail.

The difficulties hinted at above entirely disappear in the following supposition. There is no doubt, especially in accordance and with the results obtained from stellar photographs, in which Mr. Max Wolf has co-operated, that space is entirely filled with more or less extensive formations of very thinly scattered matter. With regard to their physical properties, these formations will probably show very varied constitutions, the reason for which we will leave an open question, as we do not wish to investigate it here. It is itself not very improbable that a heavenly body should get into such a cloud, but in any case it is more probable than the grazing together of two compact bodies, as is required in the above-discussed hypothesis. As soon now as the body commences to enter a cosmic cloud a surface heating will be set up at once, and indeed it must be so, whatever may be the constitution of the thinly-scattered matter. In consequence of this heating, the products of vapourizaation will form round the body; these will partly be separated from it and will adopt very quickly that velocity which the adjacent parts of the cloud possess.

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[1] Translation of an article by H. Seelinger, in *Astronomische Nachrichten* (No. 3118),.

[2] "On a General Problem of the Mechanics of the Heavens," p. 23. (München, 1892.)

[3] *Astr. Nach.*, No. 3094.

[4] *Vierteljahrsschrift der Astr. Gesellsch*, Band 27, p. 141.

[5] *Astr. Nachr.*, 3079, p. 110.

It is interesting to compare this process with a similar one, which takes place in a well-known way in the appearance of shooting stars or fireballs. In this case a compact body enters with a certain velocity into a formation of very thin matter (the upper strata of the atmosphere), is heated and partly vapourized, and a luminous tail, which is clearly visible for a long time after the sudden appearance of the meteor, marks the path which the latter has taken. The detached particles have quickly lost their relative velocities against the air, for they apparently do not partake of the movement of the meteor.

If we consider spectroscopically the star on its commencement to become bright by resistance, two superposed spectra will openly reveal themselves, one in general continuous and provided with absorption bands in consequence of the heaping up of the glowing gases, and the other in the main consisting of bright lines. Both spectra, according to the relative motion in the line of sight, will appear pressed up against one another. Thus altogether an appearance is found very similar to that observed in Nova Aurigæ, and they will agree entirely if one assumes that also those parts of the cloud nearest the body have sustained physical perturbations by a direct frictional warming of the detached particles, &c. This assumption seems to me to contain by no means a difficulty considering our lack of knowledge with respect to the properties of this cloud matter. Whether this is at all necessary I am unable to say on the ground of the publications at hand.

The investigation is important to decide whether, on the lines laid out, we can obtain a plausible explanation of the great relative velocities shown by the two spectra. When the body approaches the cloud the latter will evidently lengthen itself in the direction of the former. This lengthening will grow with the mutual approach, just as the relative velocity of the single parts of the cloud will grow towards the body. Without certain suppositions on the structure of cloud matter it is difficult to conceive of the processes of movement which take place, so we must content ourselves with contemplating the one or the other case, which admits of a closer investigation.

If, for instance, we suppose that the single particles of the cloud follow for the main part the effect of the body, they will describe conic-sections—that is, hyperbolas round the centre of the latter as forces. Their greatest relative velocity decreases quickly with the distance of the body, so that the surroundings of the latter will be filled with particles moving with very different velocities. One can easily see that no very extraordinary assumptions are necessary to suppose very great velocities for these particles that pass near the surface of the body, velocities amounting to those stated in the case of Nova Aurigæ, even if they are at the outset very small. It follows from the above that the spectral-lines of the particles which are moving from the body with such different velocities must be very much enlarged, and that to explain the different brightenings of the single parts of the lines as probably intensity maxima does not raise the least difficulty, but is a necessary accompanying phenomenon. This point seems to me to be important, for it cannot be deduced from the hypothesis of two compact masses passing close by one another, and must here lead to the rather improbable assumption of several moving bodies.

As long as the body remains in this, so to speak, atmospheric formation, the appearances above mentioned must always be called forth anew, whence it follows that the peculiarities of the spectrum conditioned by the whole state of things, not considering smaller perturbations, must on the whole remain constant for some time, a point which in the above hypothesis is at first not by any means clear. In a similar manner it will not be astonishing if the star during that time changes its brightness less strongly, while after its exit from the cloud this brightness will decrease rather rapidly. This too agrees with the light-curve in the case of the Nova. Finally, even the periodical fluctuations of the magnitude can be explained quite naturally. We call to mind here the well-known fact confirmed lately by the photographs of Max Wolf, that similar occurrences appear in shooting stars, which may, indeed, be explained with difficulty.

We must, however, in any case assume that the star entered the cosmical cloud in question about the beginning of December and left it not long before the beginning of March. Now the question is urged upon us How was it possible that for such a long time the great relative velocity could remain constant though such a resistance must have taken place that could develope the heat necessary for the glowing of the body? We are here going to decide this question by comparing the resisting power of the star to that of a meteor in the upper strata of our atmosphere.

Let us assume, quite generally, that the motion of the star in a straight line is given by the equation

$$\frac{dv}{at} = - lv_n \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad)1)$$

(1) where v is the velocity, n a positive number > 1 and λ a constant, which is directly proportional to the surface of the globular body and the density of the medium and inversely proportional to the mass of the body. We compare equation (1) with the equation for the motion of a meteor

$$\frac{dv'}{dt'} = - \lambda' v'^n$$

in which the time t' is referred to another unit selected for the purpose. If we suppose $v' = \mu v$; $t' = \nu t$; $\lambda = \lambda \nu \mu^{n-1}$. The latter equation becomes identical with (1), that is the movement of the star corresponds point to point with the motion of the meteor, if the latter equations are satisfied. Representing now m, O, r, δ, m', O$'$, r', δ', as masses, surfaces, radii, and densities of the star and meteor, and D and D$'$ the density of the cosmical clouds and the upper strata of the atmosphere in question, we have :—

$$\frac{\lambda}{\lambda'} = \frac{\mathrm{DO}m'}{\mathrm{D'O'}m} \; ; \; \nu \quad \frac{1}{\mu^{n-1}} \cdot \frac{\mathrm{DO}m'}{\mathrm{D'O'}m}.$$

or also

$$\nu = \frac{t'}{t} = \left(\frac{v}{v'}\right)^{n-} \frac{r'\delta'\mathrm{D}}{r\delta\mathrm{D}'}.$$

If we put $r = k$ times the sun's radius (=700 million metres) and $r = r'$ metres, and further corresponding to the observations of the new star $v = 30$ (unit of velocity of Earth in its orbit) and $t = 100$ days and $v' = 2$ which corresponds to a relatively quickly-moving meteor and finally $n = 2$, we have :—

$$\nu = \frac{15}{k} \cdot \frac{\mathrm{D}\delta'}{\mathrm{D}'\delta} \cdot \frac{r'}{700 \text{ millions}}$$

$$\text{and } t' = 0^s .\ 185f \; ; \; f = \frac{r'\delta'\mathrm{D}}{k\delta\mathrm{D}'}.$$

Thus the movement of the star takes place proportionally in 100 days, just as that of the meteor in 0·185 seconds if we suppose $f = 1$. As we are free to assume $\frac{\mathrm{D}}{\mathrm{D}'}$, small, we can obtain a very small fraction of a second, and since within a hundredth part of a second the movement in the highest regions of our atmosphere shows no longer a perceptible decrease of velocity, such a decrease will not enter in the case of the star. We have evidently to deal here with the same appearance which points out that small heavy objects possess a far greater resistance to air than large ones, and that with large meteors (fireballs) the air resistance, as it has been proved, influences the elements of the orbit far less than is the case with small meteors.

We have still to show that in spite of the small decrease of movement, enough energy of movement is changed into heat in order to bring the star into a surface-glowing condition, and such a condition has by all means taken place in the Nova. We must therefore calculate the quantities of heat Q and Q$'$ which is radiated in one second of time, and from a unit of surface on both bodies. If we call P and P$'$ the losses in acting power during the times t and t', v_0 and v_0' the velocities before the entrance into the resisting media, we have :—

$$\mathrm{Q} = \frac{\mathrm{P}}{\mathrm{O}t} \; ; \; \mathrm{Q}' = \frac{\mathrm{P}'}{\mathrm{O}'t'}$$

$$\text{and } \mathrm{P} = m\,(v_0^2 - v^2) \; ; \; \mathrm{P} = m'\,(v_0'^2 - v'^2)$$

and taking into consideration the above equations :

$$\frac{\mathrm{Q}}{\mathrm{Q}} = \frac{\mathrm{D}}{\mathrm{D}'} \left(\frac{v}{v'}\right)^{n+1}$$

with the above numbers $\frac{v}{v'} = 15$; n will be $= 2$

$$\frac{\mathrm{Q}}{\mathrm{Q}'} = 3375 \cdot \frac{\mathrm{D}}{\mathrm{D}'}$$

so that we can assume that the density of the cosmic medium, compared to these already very thin air strata, in which evidently the glowing of the meteor occurs, is not very dense, and that one yet gets the necessary quantity of heat.

It may be remarked that we can vary all these numbers within very wide limits without fearing any contradiction, so that we may conclude, therefore, that no difficulty in the suggested hypothesis arises from this point of view.

I have now to deduce the formulæ I have mentioned above, and it will be seen that these are very interesting.

If we take μ as the sum of two masses revolving round each other in a conic section, V the velocity, and retaining for the rest the customary nomenclature, we have for the parabola

$$\mathrm{V}^2 = k^2\mu \,.\, \frac{2}{r}\,;\;\; r = \frac{q}{\cos^2 {}^1\!/_2\, v}\,;$$

$$\tan \tfrac{1}{2}\, v + {}^1\!/_3 \tan^3 {}^1\!/_2\, v = \frac{k\sqrt{\mu t}}{q^{3/2}\sqrt{2}}.$$

Whence it follows without further difficulty :

$$\mu = \frac{\mathrm{V}^3 t}{4k^2 \sin {}^1\!/_2\, v\,[1 - {}^2\!/_3 \sin^2 {}^1\!/_2\, v]}.$$

One takes c as the velocity of the earth in its orbit with the radius R and puts the sun's mass and the mass of the earth = 1, so that $k^2 = c^2\mathrm{R}$. If we consider further that the expression

$$\sin {}^1\!/_2\, v\,[1 - {}^2\!/_3 \sin^2 {}^1\!/_2\, v]$$

can attain the maximum value $\frac{\sqrt{2}}{3}$ it follows that

$$\mu > \frac{3}{4\sqrt{2}} \cdot \left(\frac{\mathrm{V}}{c}\right)^3 \cdot \frac{ct}{\mathrm{R}}.$$

or if c be given in solar days

$$\mu > 0{\cdot}009123\left(\frac{\mathrm{V}}{c}\right)^3 t. \;\ldots\ldots\; (4)$$

To apply this to the Nova we must remember that $\frac{\mathrm{V}}{c} > 15$ because the orbital velocity may be greater than that in the line of sight. Besides, more than two months have passed since the supposed grazing of the bodies took place, which time must coincide closely with that of perihelion, up to the time that we have still spectrum observations in hand. Thus t is much greater than 60. Formula (4)—

$$\mu > 14779 \times \text{sun's mass}$$

gives thus a limit which supposes masses far too small. In reality we might perhaps assume double this without challenging contradiction.

The consideration of a hyperbolic movement takes a similar though less simple form.

If V_0 represents the velocity at an infinitely large distance, we have

$$\mathrm{V}^2 - \mathrm{V}_0^2 = \frac{2k^2\mu}{r},$$

and according to the Theoria Motus—

$$\frac{r}{a} = \frac{e - \cos \mathrm{F}}{\cos \mathrm{F}},$$

$$e \tan \mathrm{F} - \log \tan (45^\circ + 1/2\, \mathrm{F}) = \frac{k\sqrt{\mu}\,.\,t}{a^{3/2}},$$

from which it is found at once that—

$$\left.\begin{aligned} \mu &= \left(1 - \frac{\mathrm{V}_0^2}{\mathrm{V}^2}\right)^{3/2} \left(\frac{\mathrm{V}}{c\sqrt{2}}\right)^3 \frac{c\mathrm{A}}{\mathrm{R}}\mathrm{X} \\ \mathrm{X} &= \left(\frac{e - \cos \mathrm{F}}{\cos \mathrm{F}}\right)^{3/2} \cdot \frac{1}{e \tan \mathrm{F} - \log \tan (45^\circ + 1/2\, \mathrm{F})} \end{aligned}\right\} (5)$$

The expression for X, if one allows F to vary from 0°–90°, first decreases, reaches a minimum, and then increases to infinity. The minimum value can easily be determined for then

$$\frac{3}{4}\,\frac{e \sin 2\mathrm{F}}{(e - \cos \mathrm{F})^2}\,[e \tan \mathrm{F} - \log \tan (45^\circ + 1/2\, \mathrm{F})] \text{ must be } = 1.$$

This equation can be easily solved for special values of e. For the theoretical calculation which is requisite, I have employed another proceeding, as I have already computed the serial values of X for a special value of e, as the following table shows :—

	$e = 1{\cdot}5$	2·0	4·0	6·0	8·0	10·0
F = 4	10·207	14·393	24·882	32·111	37·988	43·071
8	5·224	7·302	12·554	16·182	19·135	21·689
12	3·614	4·987	8·494	10·930	12·913	14·630
16	2·852	3·866	6·505	8·348	9·853	11·156
20	2·429	3·226	5·345	6·838	8·059	9·118
24	2·178	2·827	4·603	5·866	6·902	7·802
28	2·027	2·569	4·343	5·204	6·112	6·902
32	1·941	2·400	3·753	4·740	5·555	6·265
36	1·900	2·293	3·510	4·411	5·158	5·810
40	1·892	2·234	3·345	4·181	4·877	5·486
44	1·911	2·211	3·240	4·029	4·688	5·266
48	1·953	2·220	3·187	3·941	4·574	5·131
52	2·017	2·257	3·179	3·911	4·528	5·072
56	2·101	2·323	3·217	3·936	4·547	5·086
60	2·208	2·420	3·301	4·020	4·633	5·175
64	2·341	2·552	3·438	4·170	4·797	5·351
68	2·510	2·729	3·644	4·404	5·056	5·635
72	2·728	2·968	3·944	4·754	5·451	6·070
76	3·026	3·307	4·390	5·286	6·055	6·739
80	3·477	3·830	5·108	6·152	7·048	7·843
84	4·308	4·802	0·480	7·824	8·972	9·991
88	6·991	7·938	10·960	13·320	15·321	17·091

For very large values of e the minimum of X occurs if

$$\sin \mathrm{F} = \sqrt{2/3},$$

and the minimum value of X becomes

$$\mathrm{Min\,X} = \sqrt{\frac{3^{3/2}\cdot e}{2}} = 1{\cdot}612\sqrt{e} \;\ldots\ldots\; (6)$$

But one practically commits no error if one employs (6) also for the values of e nearly equal to 1, as is evident from the following computation of the minima values taken from the above table, and calculated according to formula (6).

e	Direct.	Formula.
1	1·5	1·6
1·5	1·9	2·0
2	2·2	2·3
4	3·2	3·2
6	3·9	3·9
8	4·5	4·6
10	5·1	5·1

One obtains :—

$$\mu > 0{\cdot}0104\left(1 - \frac{\mathrm{V}_0^2}{\mathrm{V}^2}\right)^{3/2}\left(\frac{\mathrm{V}}{c}\right)^3 \sqrt{e}\,.\,t \;\ldots\ldots\; (7)$$

For the above assumptions—

$$t = 60,\; \left(\frac{\mathrm{V}}{c}\right) = 30,$$

we find

$$\mu > 16800\sqrt{e}\left(1 - \frac{\mathrm{V}_0^2}{\mathrm{V}^2}\right)^{3/2}$$

which formula holds good for values of e, which do not quite equal 1. In order to include also the parabola we suppose

$$\mu > 15000\sqrt{e}\left(\frac{\mathrm{V}^2 - \mathrm{V}_0^2}{\mathrm{V}^2}\right)^{3/2} \;\ldots\ldots\; (7a)$$

Thus in this case we result in extremely large masses, which are not very probable, or we must assume that $\frac{\mathrm{V}_0}{\mathrm{V}}$ = very nearly 1. Even for $\frac{\mathrm{V}_0}{\mathrm{V}} = 0{\cdot}9$, according to the above formula, $\mu > 1200\sqrt{e}$, and we may consider the above-given assertion as justified. It has already been remarked that this suggested inequality proves only that μ is very much greater than the right side (of the equation).

It is easy to find a higher limit for μ if $\frac{\mathrm{V}_0}{\mathrm{V}}$ does not differ much from unity.

If we put $\frac{\mathrm{V}^2 - \mathrm{V}_0^2}{\mathrm{V}^2 + \mathrm{V}_0^2} = \nu$, we obtain $\cos \mathrm{F} = \nu e$, and according to formula (5) :

$$\mu = \left(\frac{1 - \nu}{1 + \nu}\right)^{3/2}\left(\frac{\mathrm{V}}{c}\right)^3 \frac{ct}{\mathrm{R}} \cdot \frac{\nu}{e\nu \tan \mathrm{F} - \nu \log \tan (45^\circ + 1/2\,\mathrm{F})}.$$

Given t, e, and v, we can calculate the right-hand side. But we seek, however, the maximum value of

$y = e\nu \tan F - \nu \log \tan (45° + 1/2F) = \sin F - \nu \log \tan (45° + 1/2F)$

by determining e as function of ν. It is

$$\frac{\partial y}{\partial e} = \left(\cos F - \frac{\nu}{\cos F}\right)\frac{\partial F}{\partial e} = \frac{\nu(1 - \nu e^2)}{e\sqrt{1 - \nu^2 e^2}}.$$

Thus y increases so long as $e < \frac{1}{\sqrt{\nu}}$, and decreases continually for $e > \frac{1}{\sqrt{\nu}}$. The maximum for y takes place when $e^2 = \frac{1}{\nu}$, and is

$$y = \sqrt{1 - \nu} - \nu \log\left(\frac{1 + \sqrt{1 - \nu}}{\sqrt{\nu}}\right).$$

Thus we have

$$\mu > \frac{ct}{R}\left(\frac{V}{c}\right)\left(\frac{1 - \nu}{1 + \nu}\right)^{3/2} \cdot \frac{\nu}{\sqrt{1 - \nu} - \nu \log\left(\frac{1 + \sqrt{1 - \nu}}{\sqrt{\nu}}\right)}; \quad . \ (8)$$

and with $\frac{V}{c} = 30$ and $t = 60$ days,

$$\mu > 27800\left(\frac{1 - \nu}{1 + \nu}\right)^{3/2} \frac{v}{\sqrt{1 - \nu} - \nu \log\left(\frac{1 + \sqrt{1 - \nu}}{\sqrt{\nu}}\right)}.$$

For the above example $\frac{V_0}{V} = 0·9$ results $\mu > 2800$ as considerably larger masses than formerly.

I have now further to prove that a very close proximity of the two bodies can have only taken place for a very short space of time. To do this we use the following relations.

We find above for the parabola:

$$\mu = \frac{V^3 t}{4k^2 x}; \ x = \sin \tfrac{1}{2}v(1 - 2/3 \sin^2 1/2v).$$

It follows, therefore, that

$$V^2 = \frac{2k^2\mu}{\nu}$$

$$r = \frac{Vt}{2x}.$$

Thus we have

$$v > \frac{3}{2\sqrt{2}}. \quad Vt = 1 . 06Vt \quad . \ . \ . \ . \ . \ . \ (9)$$

For the hyperbola we have

$$r = \frac{2k^2\mu}{V^2 - V_0^2},$$

and, according to formula (5)

$$2k^2\mu = \frac{(V^2 - V_0^2)^{3/2}}{\sqrt{2}}tX.$$

Therefore,

$$r = \frac{\sqrt{V^2 - V_0^2}}{\sqrt{2}}tX.$$

For eccentricities which are not very nearly equal to 1, we had

$$X > \frac{3^{3/4}}{\sqrt{2}}. \quad \sqrt{e},$$

and it is certainly

$$r > \frac{3^{3/4}}{2}\sqrt{e}\sqrt{V^2 - V_0^2} . t > 1·05\sqrt{V^2 - V_0^2}t \quad . \ (10)$$

For $V_0 = 0$.

(10) is naturally changed into (9). For the hyperbola, however, it is possible to suggest a second relationship.

Since

$$2\frac{a}{r} = \frac{V^2 - V_0^2}{V_0^2}.$$

(5) can also be written

$$k^2\mu = \left(\frac{a}{r}\right)^{3/2} V_0^3 tX.$$

and because $k^2\mu = aV_0^2$, it follows that

$$r = \sqrt{\frac{a}{r}} . V_0 tX = V\,ty,$$

where

$$y = \frac{e - \cos F}{\cos F} \cdot \frac{1}{e \tan F - \log \tan (45° + 1/2F)}.$$

An easy calculation yields now

$$\frac{\partial y}{\partial F} = \frac{-1}{e \sin F - \cos F \log \tan (45° + 1/2F)} . [(1 + e^2) \cos F - 2e + e \sin F \log \tan(45° + 1/2 F)].$$

It is quite evident that the quantities in brackets always remain positive, for it is

$\log \tan (45° + 1/2 F) = 2 \tan \tfrac{1}{2} F + \tfrac{2}{3} \tan^3 1/2 F + \ldots > 2 \tan 1/2 F$,

and in consequence of it the quantity in brackets $> (e - 1)^2 \cos F$. Thus, $\frac{\partial y}{\partial F}$ is negative, and y decreases as F increases. From this it follows that $y > 1$, and the relation $r > V_0 t$, is the result.

If we apply this formula to Nova Aurigæ, we obtain for

$$\frac{V_0}{V} = 0·5 \quad \sqrt{V^2 - V_0^2} = 108 \text{ miles}, \quad V_0 = 60$$

0·6	96	72
0·7	86	84
0·8	72	96
0·9	—	108

In the vicinity of perihelion the velocity has been under every condition greater than 120 miles, and we shall therefore obtain values of r that are considerably too small, by supposing $r > t$ × 85 miles. One day before or after perihelion it is therefore certain that $r > 7·3$ million miles.

It will therefore hardly be possible to assume that any noticeable influence of the supposed two bodies can have lasted longer than a few hours.

Since the above article was written Nova Aurigæ has by its reappearance attracted considerable attention, and especially by the observation as made by Prof. Barnard. With regard to this reappearance one must necessarily see an evident confirmation of the critical part of my article. Nor has my hypothesis been contradicted in any way, for it is evident in itself that the supposed formations of the nebulous or dusty matter are more copious in certain parts of space, and one may have different ideas of the distribution of density of these formations.

To the observation made by Prof. Barnard (*Astr. Nach.*, 3114) I wish to add the following remarks. I had formed an idea of the whole process which caused the outburst of the Nova, which idea is as perfectly represented in Prof. Barnard's drawing, kindly communicated to me by Prof. Kreutz, as I could expect. During the appearance of the Nova in the winter nothing similar was seen so far as I know. It does not follow from this, therefore, that it did not exist, and it would also have been possible to have expected information from the photographs as has often occurred before. I applied on this account to Dr. Wolf, in Heidelberg, and asked him whether he had photographs of the region of the Nova at that time, and whether, perhaps, any nebulous object was to be seen on them; but, unfortunately, Dr. Wolf did not possess such photographs. It remains doubtful, I am sorry to say, whether so delicate an object would have been visible on the plates.

W. J. LOCKYER.

HINTS FOR COLLECTORS OF MOLLUSKS.[1]

AFTER the collector has brought home the spoils of his excursion there is still a good deal to be done before the wet and dirty shells, covered with parasitic growths or inhabited either by the original mollusk or some hermit crab, will be ready to be placed in the cabinet. Some of them, if living, may find a temporary place in an aquarium for the study of their habits, but, for the most part, the collector will wish to prepare his specimens either for anatomical use in the future or as dry specimens for his cabinet. The preparation of mollusks for anatomical purposes has been described in a special chapter of these instructions. For ordinary rough work nothing is better than clean 90 per cent. alcohol diluted with a proper proportion of water. If the specimens are large they should be first put into a jar kept for that special purpose, in which the alcohol is comparatively weak, having, say, 50 per cent. of water added to it. After the immersion of specimens in this jar for several days the fluids will have been extracted by the alcohol, and a specimen can then be removed, washed clean of mucus and dirt, which will almost always be found about the aperture of a spiral shell, and

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[1] Reprinted from "Instructions for Collecting Mollusks, and other Useful Hints for the Conchologist," by William H. Dall; issued by the Smithsonian Institution as Part G of *Bulletin* of the U. S. National Museum, No. 39.